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TONOLLI V. (1961). Study on the dynamics of the population of a copepod (Eudiaptomus vulgaris Schmeil) Memorie Ist.ital Idrobiol. 13, 179-202.

Translated by W. J. P. Smyly

Eudiaptomus vulgaris Schmeil is the most abundant copepod in Lake Maggiore and forms also, in respect to other entomostraca, the most important element, through its average biomass and becuase it is fairly numerous throughout the year.

Plankton samples collected in a systematic and quantitative way, as one will describe shortly, gave here the opportunity to study some aspects of the dynamics of the population of this copepod, in safety in view of the uncertainty which in this kind of study can ensue when samples are taken only at a single station - in consequence of the changes in size of population between different water masses.

The material upon which this research is based was collected in the course of 14 cruises made during one year on Lake Maggiore (Tonolli, V., 1960 and 1961). During each cruise, plankton was collected at 12 stations, roughly equidistant and situated on the long axis of the lake (Fig. 1). About collecting methods, it will suffice to record here that the collections were made with plankton-samplers (Clarke and Bumpus) placed in the water open with the boat in uniform motion at the sampling station. The samplers were allowed to descend to a depth of 50 m and then raised to the surface, keeping to the constant speed of the winch. One obtained thus quantitative collections of about 4000 litres of water, representing equally each strata between the surface and 50 m.

On account of the size of the lake, it was impossible to sample all twelve stations on the same day: generally stations 1-7 were sampled one day and stations 8-12 on the following. Care was taken to make the collections in the middle of the day (10 a.m. - 2 p.m.) to avoid disturbance associated with the vertical migrations, which, on the other hand, one ought to consider for in Lake Maggiore it generally lies within the first 50 m. Dates of collection are shown successively in the text with a roman numeral.

	Stazione	Data			Stazione	Data	
IX a	1- 7	9 Settembre	1957	IV	1- 5	30 Aprile	1958
	8-12	10 Settembre	1957		6- 7	1°Maggio	1958
					8-12	29 Aprile	1958
X	1- 7	9 Ottobre	1957	V	1- 4	28 Maggio	1958
	8-12	10 Ottobre	1957		5-12	29 Maggio	1958
XI	1- 7	14 Novembre	1957	VI	1- 7	16 Giugno	1958
	8-12	15 Novembre	1957		8-12	17 Giugno	1958
XII	1- 7	16 Dicembre	1957	VII, 1	1- 7	7 Luglio	1958
	8-12	17 Dicembre	1957		8-12	8 Luglio	1958
I	1- 7	27 Gennaio	1958	VII, 2	1- 7	28 Luglio	1958
	8-12	28 Gennaio	1958		8-12	29 Luglio	1958
III, 1	1- 7	5 Marzo	1958	VIII	1- 7	19 Agosto	1958
	8-12	6 Marzo	1958		8-12	21 Agosto	1958
III, 2	1- 7	31 Marzo	1958	IX b	1- 7	9 Settembre	1958
	8-12	1°Aprile	1958		8-12	10 Settembre	1958.

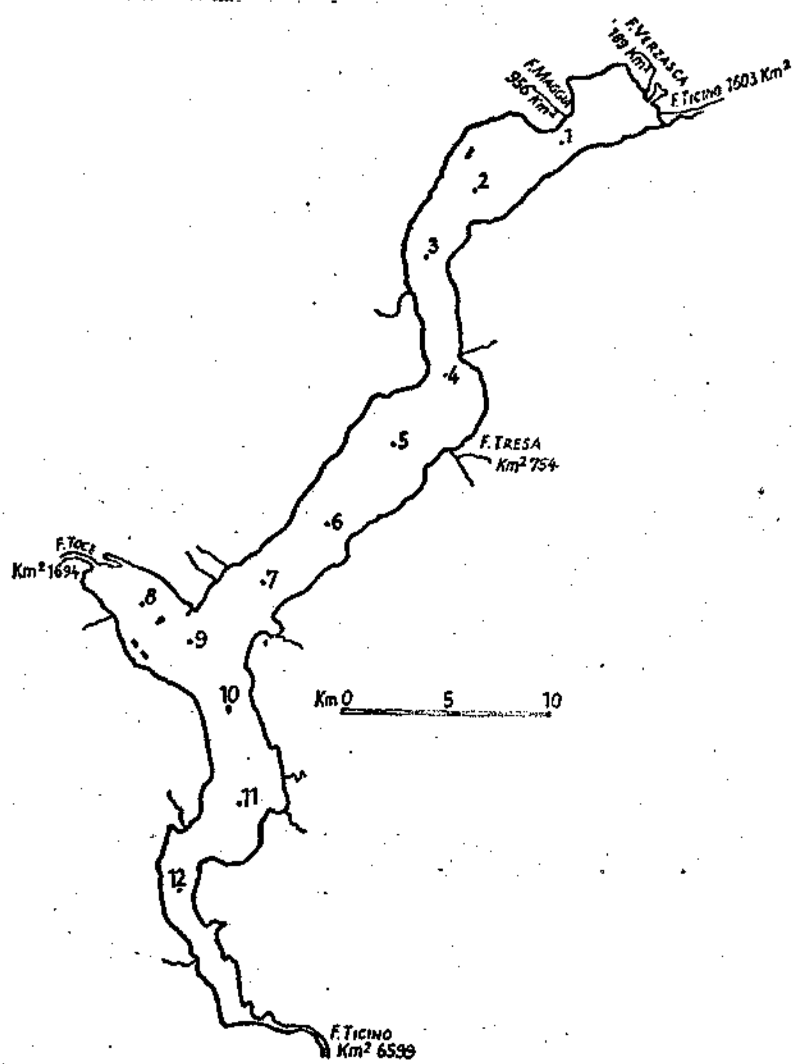

Fig. 1. - Localizzazione delle stazioni di raccolta nel Lago Maggiore.

The individual components of the population of <u>Eudiaptomus vulgaris</u> (adult males, adult females with or without eggs, copepodid stages, nauplii, eggs) are always given in no/m^3 from between the surface and 50m from a column of 200 cm^2 base area and 50m depth.

The analysis of the material included biometrical evaluation of adult females. From each of the 168 plankton samples available (12 stations and 14 dates) 50 adult ♀♀ were taken out, and measured for two characters (see Fig. 2): a) the shortest distance from the lateral projection of the articulation between the 1st and 2nd segments of the cephalothorax to the most prominent of the cephalic convexity and b) the total length of the 1st antenna from its insertion to the cephalothorax to the end of the last segment. The measurements were made on a highly magnified projection of each example with the use for measuring the antenna, of a "curvimetro".

Data	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93...96
IX a					3	3	26	45	69	55	38	42	9	5	3	1	1										
			1	*3*		*4*	*10*	*19*	*38*	*58*	*60*	*47*	*36*	*15*	*8*	*1*											
X			3	2	5	14	27	47	64	55	39	22	14	6	2												
	1		*1*	*2*	*3*	*3*	*15*	*31*	*43*	*45*	*61*	*35*	*31*	*24*	*4*	*1*											
XI							1	6	6	8	24	31	39	44	51	32	34	15	6		2	1					
							1	*1*	*8*	*6*	*11*	*17*	*27*	*45*	*45*	*31*	*46*	*22*	*24*	*9*	*5*	*2*					
XII									2	4	5	15	15	36	39	53	47	38	25	16	1	4					
									1	*4*	*9*	*8*	*24*	*29*	*41*	*37*	*42*	*50*	*32*	*13*	*4*	*3*	*2*				*1*
I										2	6	6	12	30	44	53	56	39	25	15	7	3	1				1
				1					*3*	*2*	*10*	*9*	*20*	*27*	*41*	*46*	*52*	*31*	*22*	*19*	*11*	*3*	*1*	*1*			*1*
III, 1									1		3	7	8	33	44	44	57	31	30	23	9	7	2	1			
										1	*6*	*10*	*15*	*29*	*34*	*46*	*53*	*34*	*37*	*25*	*8*	*1*		*1*			
III, 2									1		2	7	6	20	34	48	57	50	42	19	9	4		1			
											1	*4*	*5*	*15*	*30*	*37*	*64*	*48*	*44*	*30*	*10*	*9*		*2*		*1*	
IV											4	4		13	23	26	36	31	63	47	23	16	9	4		1	
													1	*7*	*17*	*22*	*53*	*37*	*57*	*44*	*32*	*15*	*7*	*4*	*3*	*1*	
V														6	8	21	32	35	62	59	46	14	9	7	1		
													1	*6*	*13*	*17*	*39*	*47*	*52*	*53*	*36*	*23*	*8*	*4*	*1*		
VI					1	1	2	5	7	16	18	15	19	19	27	25	29	29	34	28	11	9	2	1	2		
								4	*2*	*8*	*5*	*7*	*13*	*22*	*26*	*30*	*41*	*47*	*42*	*25*	*20*	*7*		*1*			
VII, 1						2	1	5	6	7	10	20	20	42	37	40	32	34	22	16	4	2					
									3	*10*	*12*	*19*	*32*	*31*	*45*	*39*	*29*	*23*	*25*	*18*	*9*	*3*	*2*				
VII, 2					1		3	6	24	41	41	40	29	31	28	19	14	10	7	3	2		1				
						1	*3*	*5*	*7*	*17*	*31*	*37*	*42*	*42*	*40*	*25*	*19*	*10*	*11*	*7*	*3*						
VIII			2	5	14	19	44	36	40	44	37	18	19	14	3	2	1	1	1								
				1	*5*	*11*	*19*	*14*	*39*	*54*	*35*	*39*	*30*	*33*	*8*	*4*	*5*	*2*	*1*								
IX b			1	4	15	18	60	47	40	56	25	15	7	9	1	1	1										
		1		*3*	*5*	*7*	*27*	*17*	*45*	*34*	*35*	*41*	*23*	*28*	*18*	*7*	*7*	*1*		*1*							

Tabella 1. - Ripartizione in classi di grandezza (× 5,319 = μ) delle misure del I segmento del cefalotorace di 300 individui di *Eudiaptomus vulgaris* ♀ provenienti dalle Stazioni da 1 a 6 e *da 7 a 12* (50 individui per Stazione).

Data	17	.5	18	.5	19	.5	20	.5	21	.5	22	.5	23	.5	24	.5	25	.5	26	.5	27	.5	28
IX a			8	24	22	29	48	39	42	31	28	12	11	2	1	1	1	1					
			14	*23*	*34*	*32*	*55*	*38*	*38*	*26*	*20*	*8*	*7*	*3*	*1*	*1*							
X			7	20	23	25	36	45	36	41	31	20	11	3	2								
			4	*16*	*18*	*24*	*37*	*34*	*53*	*29*	*40*	*21*	*17*	*1*	*5*	*1*							
XI						1	10	7	16	31	35	44	53	34	34	22	9	3	1				
						4	*14*	*10*	*13*	*17*	*32*	*39*	*34*	*38*	*39*	*25*	*16*	*10*	*8*		*1*		
XII							1	1	2	7	14	14	30	34	49	38	41	23	24	13	8	1	
							2	*5*	*7*	*11*	*14*	*19*	*37*	*34*	*44*	*42*	*32*	*18*	*20*	*7*	*7*		*1*
I				3	2	5	12	11	15	19	34	33	40	33	34	12	29	7	8	3			
					2		*12*	*16*	*17*	*27*	*24*	*23*	*37*	*37*	*46*	*21*	*19*	*3*	*10*	*1*	*3*	*2*	
III, 1						1	1	3	2	7	15	15	27	34	39	47	29	39	24	11	4	2	
				1		*3*	*4*	*8*	*1*	*8*	*17*	*24*	*26*	*34*	*40*	*45*	*36*	*25*	*13*	*9*	*2*	*2*	*2*
III, 2							2	3	6	8	11	18	21	29	45	46	42	27	24	10	6	2	
							5	*2*	*6*	*12*	*10*	*19*	*19*	*43*	*37*	*42*	*44*	*26*	*16*	*14*	*3*	*2*	
IV							2	3	7	9	13	27	27	41	40	33	35	25	15	16	5	2	
							3	*3*	*5*	*2*	*14*	*9*	*21*	*29*	*42*	*41*	*54*	*27*	*19*	*15*	*8*	*8*	
V							1	2	3	4	12	20	12	35	35	41	83	43	28	20	7	4	
							3	*3*	*4*	*9*	*14*	*20*	*13*	*37*	*33*	*38*	*46*	*35*	*23*	*15*	*4*	*1*	*2*
VI			4	4	14	5	31	15	35	29	47	31	32	23	13	7	2	5	2		1		
				3	*8*	*7*	*27*	*23*	*25*	*22*	*39*	*24*	*43*	*22*	*18*	*18*	*13*	*2*	*3*	*2*	*1*		
VII, 1			2	9	18	12	30	11	44	30	43	15	34	16	14	9	9	1	3				
				8	*17*	*17*	*38*	*16*	*34*	*28*	*44*	*26*	*29*	*18*	*9*	*9*	*6*		*1*				
VII, 2		4	10	15	24	16	34	46	25	39	34	19	10	7	9	3	3		1	1			
			3	*7*	*13*	*17*	*19*	*37*	*35*	*33*	*44*	*29*	*20*	*22*	*8*	*5*	*4*	*2*	*2*				
VIII	2	7	7	25	34	26	41	47	30	34	19	9	14	1	1	1		1		1			
		1	*10*	*19*	*19*	*21*	*40*	*35*	*46*	*22*	*37*	*16*	*20*	*5*	*8*		*1*						
IX b			9	31	26	47	44	31	34	23	24	12	7	3	6	3							
			6	*24*	*15*	*29*	*39*	*27*	*40*	*32*	*32*	*17*	*12*	*10*	*9*	*5*	*2*		*1*				

Tabella 2. - Ripartizione in classi di grandezza (× 53,763 = μ) delle misure della I antenna di 300 individui di *Eudiaptomus vulgaris* ♀ provenienti dalle Stazioni da 1 a 6 e *da 7 a 12* (50 individui per stazione).

In much of what follows, it is deemed necessary to group in two series each of six stations (stations 1-6 northern group and 7-12 southern section of the lake) the furnished values of the collected material at each station. This is done for the following reasons. In Lago Maggiore, it has been established (Tonolli 1960) that the isothermal levels have a tendency to be arranged obliquely with maximum superficialness at the north end and sinking at the south. This leads to diverse aquatic regions especially at the extremities with the consequence of a lack of synchronisation of the same biological phenomena or the possibility that the same or other biological phenomena come about in different thermal conditions; which, in the case of copepods can bring about differences in size and structure of populations.

The two arms of Lago Maggiore, in which are found respectively stations 1-6 and 7-12, are sufficiently isolated from each other through the character and direction of the dominant winds to have different thermal structures. On the other hand, none of the twelve stations has maintained or changed the structure of its planktonic biocoenosis in accordance with particular pre-existing situations, coming thus to fall short of the premise of an individuality of stations and leading indeed to the frequent recognition of a grouping of the aspects of the succession of biocoenoses between each of the two basins.

The results of the biometrical observations are tabulated (see Tables 1 and 2) according to size-groups while Table 3 gives the mean measures of two characters at different seasons.

The seasonal changes are also this time in accord with what one knows of the argument: the larger dimensions are reached by the individuals which have completed their development in coldish water, assuming a rough inverse correlation between temperature and body-size. It may be noted that in stations 7-12, (the more southern have slightly higher temperatures) the dimensions, especially of the cephalothorax are rather higher than those of the contemporaneous individuals of the northern stations. This with difficulty one can attribute to the effect of a passive transport owing to the predominant current in the lake from north to south and thence towards the outflow, because, in the summer time, the biometrical values for the southern population are always larger. Hence it is probable that the somatic dimensions, bound up principally with the nutrient temperature, depend also on other factors, e.g. on the availability of food.

One can see also how the maximum length of the first antenna precedes in time that of the cephalothorax and how, while the series of biometrical values of the cephalothorax are arranged in an orderly way, the antenna in the month of January shows a considerable reduction in both the groups of stations, which is not in accord with the observations either preceding or following. The phenomenon is represented schematically in Fig. 3 which shows jointly the biometrical modifications of the entire population of the lake (all the 12 stations) and the mean temperature variations in the water strata from which the samples of <u>Eudiaptomus vulgaris</u> were collected, namely from the surface to 50 m.

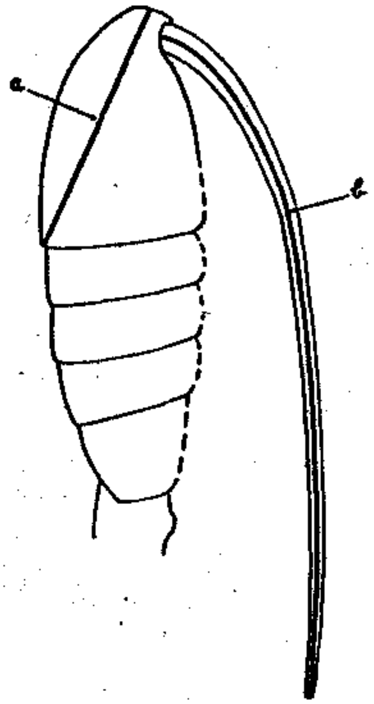

Fig. 2. - Schema delle misure assunte su *Eudiaptomus vulgaris* femmina.

	I° segmento del cefalotorace		I^a antenna	
	St. 1-6	7-12	St. 1-6	7-12
IX a	μ 403.1	408.1	μ 1104.7	1090.2
X	400.8	406.7	1111.8	1122.4
XI	426.4	432.4	1223.3	1235.9
XII	436.4	437.5	1303.8	1286.4
I	438.5	437.4	1230.5	1237.0
III, 1	440.2	439.2	1302.2	1284.3
III, 2	441.5	444.1	1301.5	1294.4
IV	448.7	450.5	1291.2	1312.3
V	452.9	451.9	1316.4	1304.3
VI	435.3	440.7	1172.6	1194.1
VII, 1	432.6	434.0	1164.8	1158.9
VII, 2	419.2	424.3	1122.5	1157.7
VIII	400.7	408.8	1094.8	1119.1
IX b	397.8	408.8	1096.2	1124.7
$\overline{M}$	426.7	430.3	1202.7	1208.6

Tabella 3.

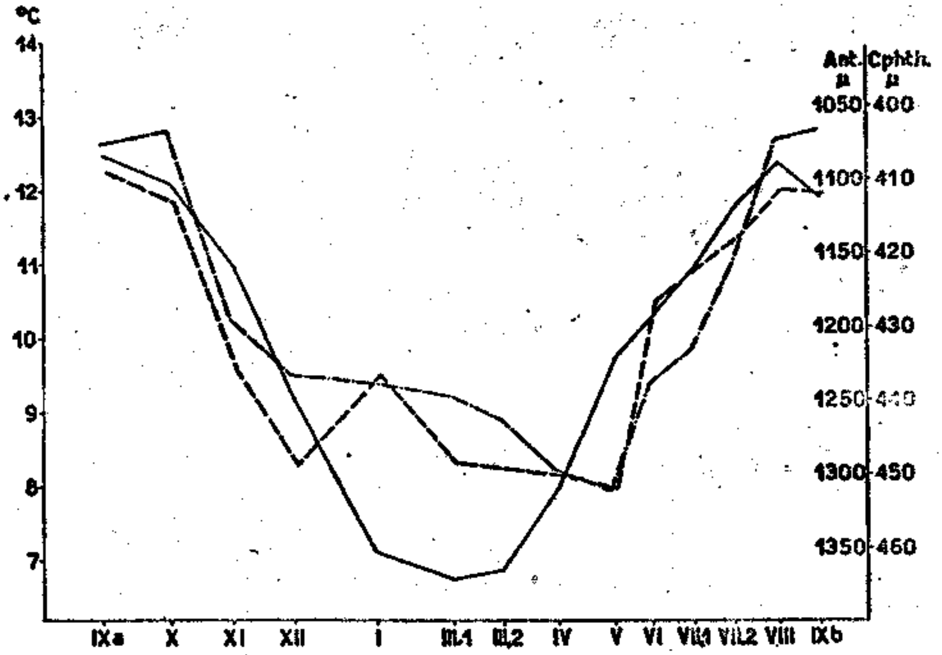

Fig. 3. - Variazione annuale della temperatura e di caratteristiche biometriche di *Eudiaptomus vulgaris* femmina: media delle 12 stazioni. ———: temperatura media dello strato d'acqua 0-50 m; — — — —: lunghezza della I antenna; —·—·—: lunghezza del I segmento del cefalotorace.

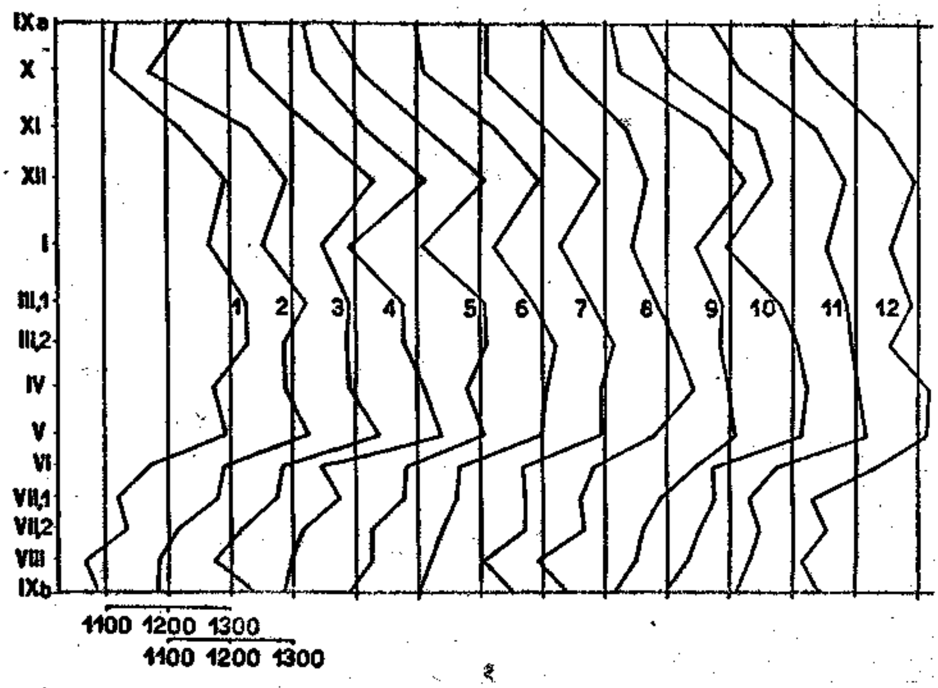

Fig. 4. - Modificazione annuale (in micron) della lunghezza della I antenna di *Eudiaptomus vulgaris* femmina nelle parcelle di popolazione raccolte in ognuna delle 12 stazioni.

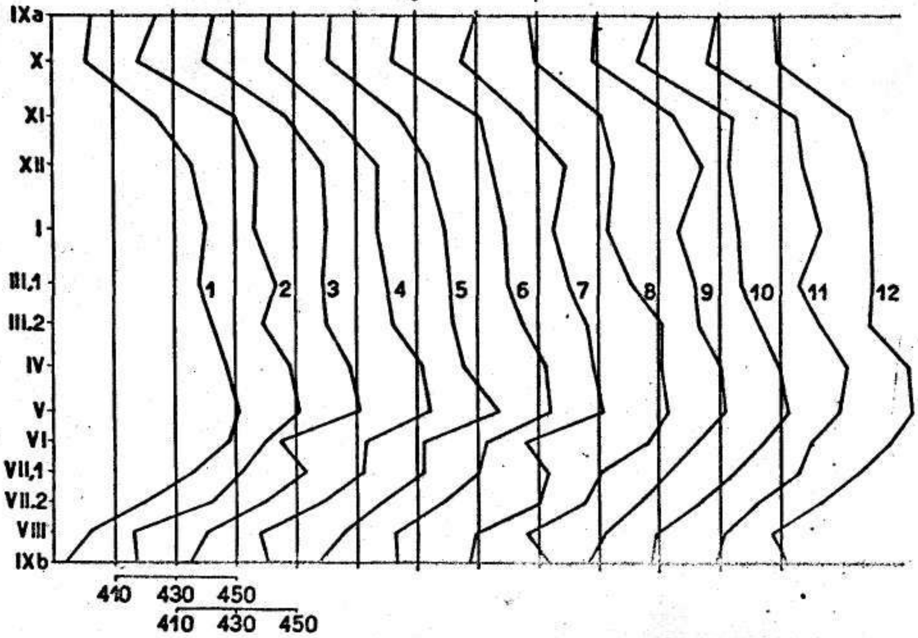

Fig. 5. - Come in Fig. 4, per il I segmento del cefalotorace.

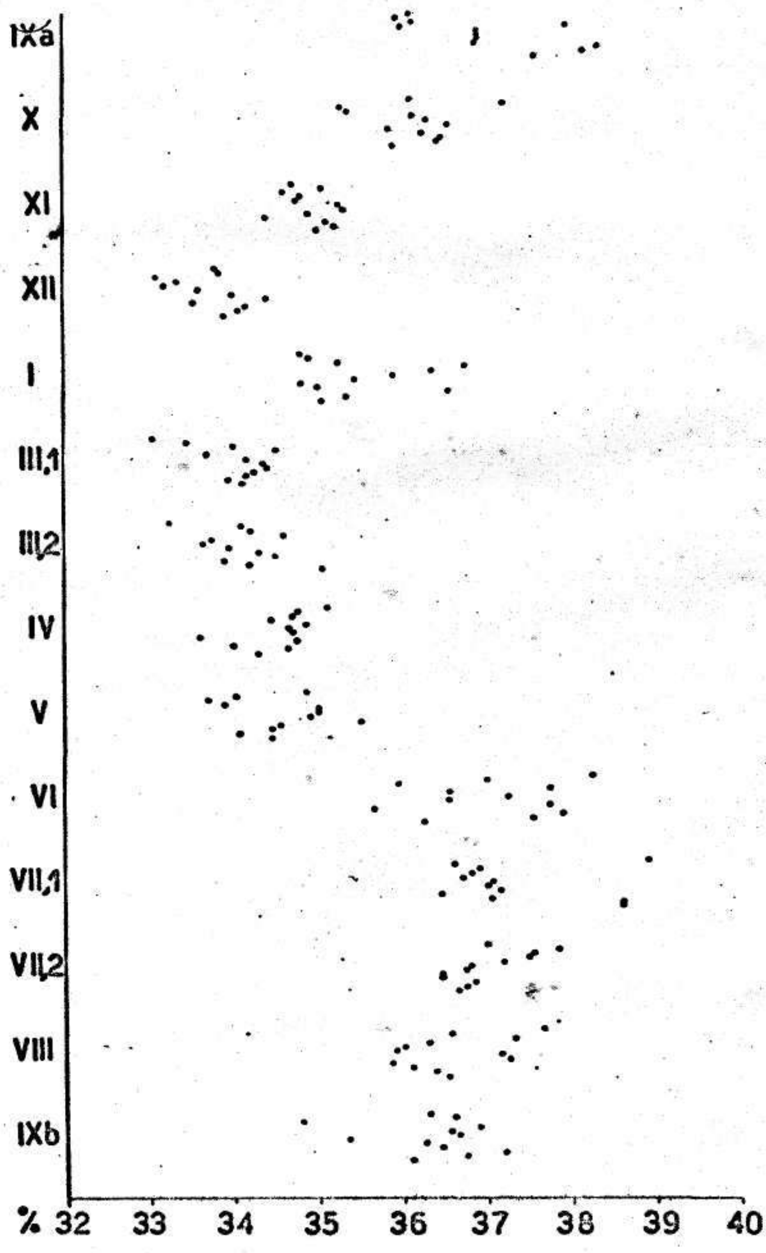

Fig. 6. - Distribuzione durante l'anno dei valori dei rapporti percentuali tra le lunghezze della I antenna e del I segmento del cefalotorace. Per ogni data, i 12 punti rappresentano, dall'alto al basso, tale rapporto, per le popolazioni dalla Stazione 1 alla 12.

If we examine in greater detail, in Fig. 4 and 5, the biometrical modifications of the two characters, present in the individuals collected in each of the twelve stations we are able to obtain some additional information. The general picture of the graphs for each of the two characters is similar enough in all the stations. The major irregularity one sees in the antenna for the data from January (I) when in most of the stations (3, 4, 5, 6, 7, 9 and 10) the inflection in reduction is clearly more pronounced than in the stations 1, 2, 8, 11 and 12. These last are situated in the terminal inlets of the lake where the depths are less than in the main part of the lake always shallower than 300 m, the stations 1, 2, 8, 11 and 12 have in fact depths respectively of 90, 200, 100, 120 and 70 m.

At the end of January, the process of homogenising of the temperature is already pushed from the surface to considerable depths and hence there is nothing to stop water from the deep reaching the surface as a result of wind action.

It is noted that many zooplankton populations, through having the largest numbers in the superficial strata, if they migrate into deeper water become more or less isolated from the greater part of the population, as we have had occasion to see in Eudiaptomus vulgaris, always in Lago Maggiore, carried out by collections horizontal to great depths by day and by night. It is possible perhaps to think that the strong and inconsistent modifications of the biometrical values observed in January depend on the mixture, which the convective currents of the water bring about in this season, between individuals more or less confined to different levels and which hence develop under different nutrient conditions.

That the biggest amplitude of the phenomenon is observed in the deeper stations can be simply credited to the greater availability along the water column of deep individuals which can easily reach the surface by active migration in half an hour in homogeneous water.

In Fig. 6 are given the percentage figures between the lengths of the antenna and those of the 1st segment of the cephalothorax for the bulk of the populations collected during the entire year at the twelve stations in the lake.

The general arrangement of the distribution of the points is that of a sinusoid, from which one can affirm that in the large individuals of winter the antenna assumes a proportionately greater development than in the summer individuals of more modest dimensions. In January one sees how the position of the points have values like they have in October, as with the absolute dimension, above all the cephalothorax but also the autumn increased at that season.

Referring to the values of density with which females of Eudiaptomus vulgaris populate the water column at different stations and seasons, the relative distribution in size groups of the length of the 1st segment of the cephalothorax (Table 1) it has been possible to construct the diagram, as in Fig. 7 which shows, this time as means of the whole lake, the variations of the biometrical structure within the modifications of the dimensions of the population in the different seasons. One can see with

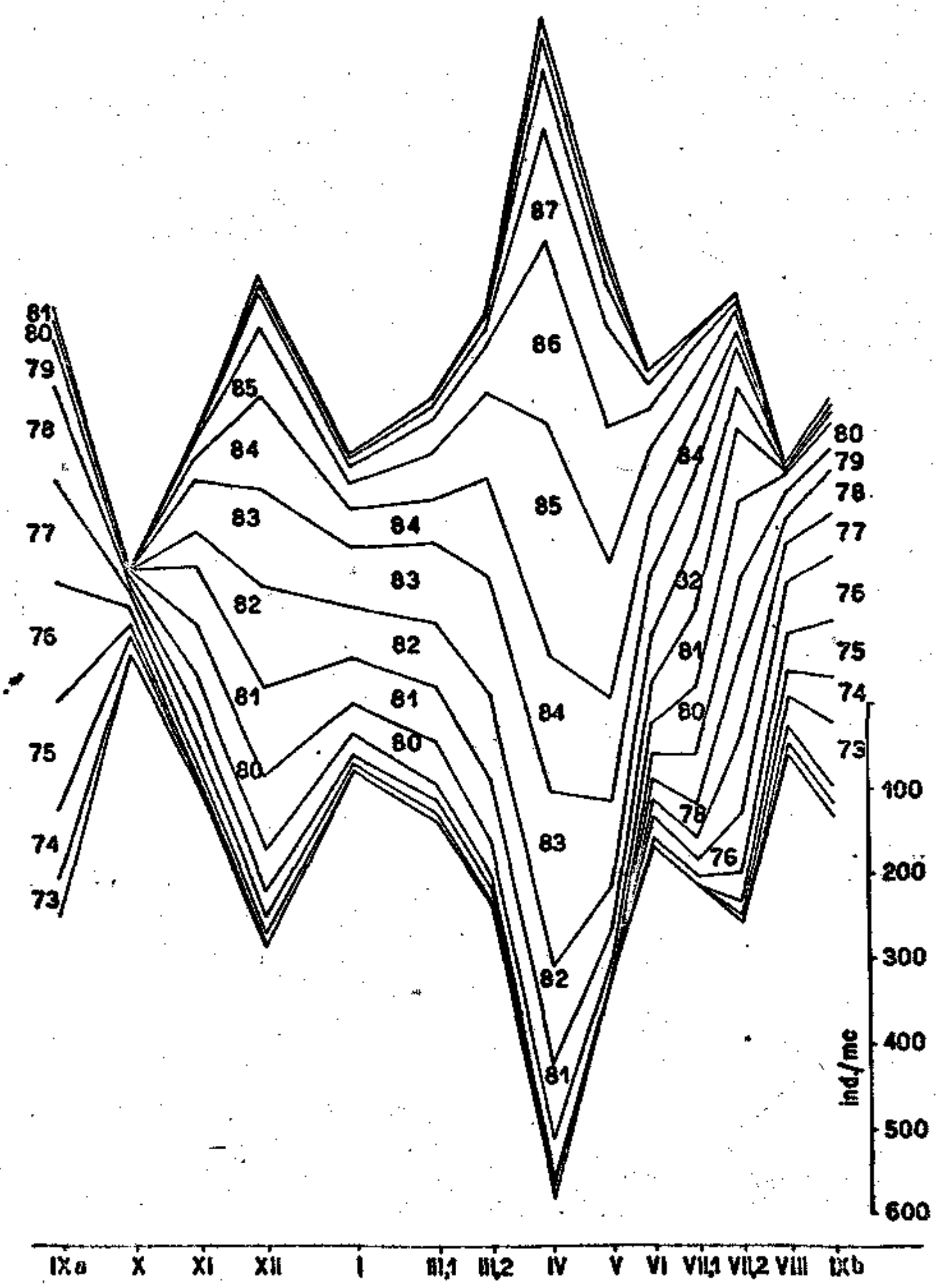

Fig. 7. - Modificazione stagionale della densità di popolamento di *Eudiaptomus vulgaris* femmina per tutto il lago e variazioni delle partecipazioni delle diverse classi di grandezza per la lunghezza del I segmento del cefalotorace (× 5,319 = micron).

good evidence that the annual cycle of the different size-groups have the values of a true and accurate seasonal succession. The convergence of more lines in certain particular seasons (e.g. in XII, V, VII and VIII) shows clearly the disappearance of preceding classes and representing also in considerable measure the arrival of new classes. There is good agreement between the classes present and their relative importance at the end of the annual cycle (IXa and IXb).

Applying this procedure, both for the measurement of the cephalothorax as well as the antenna and keeping distinct the regions just cited, the observations made at the stations 1-6 and 7-12, one can define for each date the biometric structure in the two water masses of Lago Maggiore: in other words, the absolute frequency in the population of the different biometrical orders. The comparison between such frequencies for one date compared with the next allows one to establish how many were the copepodids which in that interval of time have reached the adult stage (in as much as one has determined a numerical increase in the biometrical groupings of appendages, or absolutely as much as individuals of the same size were not pre-existing) and obviously, for different reasons, how many adults at each census were lost and how many survived. This method is in agreement with the fact that increase in size stops on attainment of the adult state. This method is analogous to that, used at one time, for studying the phenomenon of dynamics of a population in the populations (determination of age, weight, length) and will be able to permit significant research in each species of copepod living in environments where there is evidence of a seasonal cycle in temperature. At all events they will be obliged to be chosen with attention to those characters (biometrical markings) which give greater assurance of consistent seasonal modifications.

In the case in question, we have been fortunate in coming across two characters which present a certain allometry in their modifications (see Fig. 6), which results especially in a more exact appreciation of the value of recruitment of neoadults. Naturally, if one had examined a number of characters greater than two, the precision would be increased, in as many as lead to additional information, especially if the correlation was not much higher.

Also as regards natural mortality, it is possible to criticise the validity of these measures in the sense that one might have obtained a value less than the actual: mortality occurring in the biometrical classes in which one has determined an increase, mortality of neoadults having occurred before their census, both deficiencies which may concern classes of long ago and which presumably do not involve intolerable errors.

The results of this working out are expressed graphically in Fig. 8 and 9, respectively for the situations found in the portions of the lake where are the stations 1-6 and 7-12. The graphs are divided into three sections. At the extreme right, we have the diagrams, in reduced scale, of the density in m^3 of the population of Eudiaptomus vulgaris subdivided into individual adults (males and females) copepodids and nauplii. The section in the centre and left have a common line of origin and they show on one side the variations in the time of the death of the female adults in a m^3 of water and on the other that of the density of the population in a

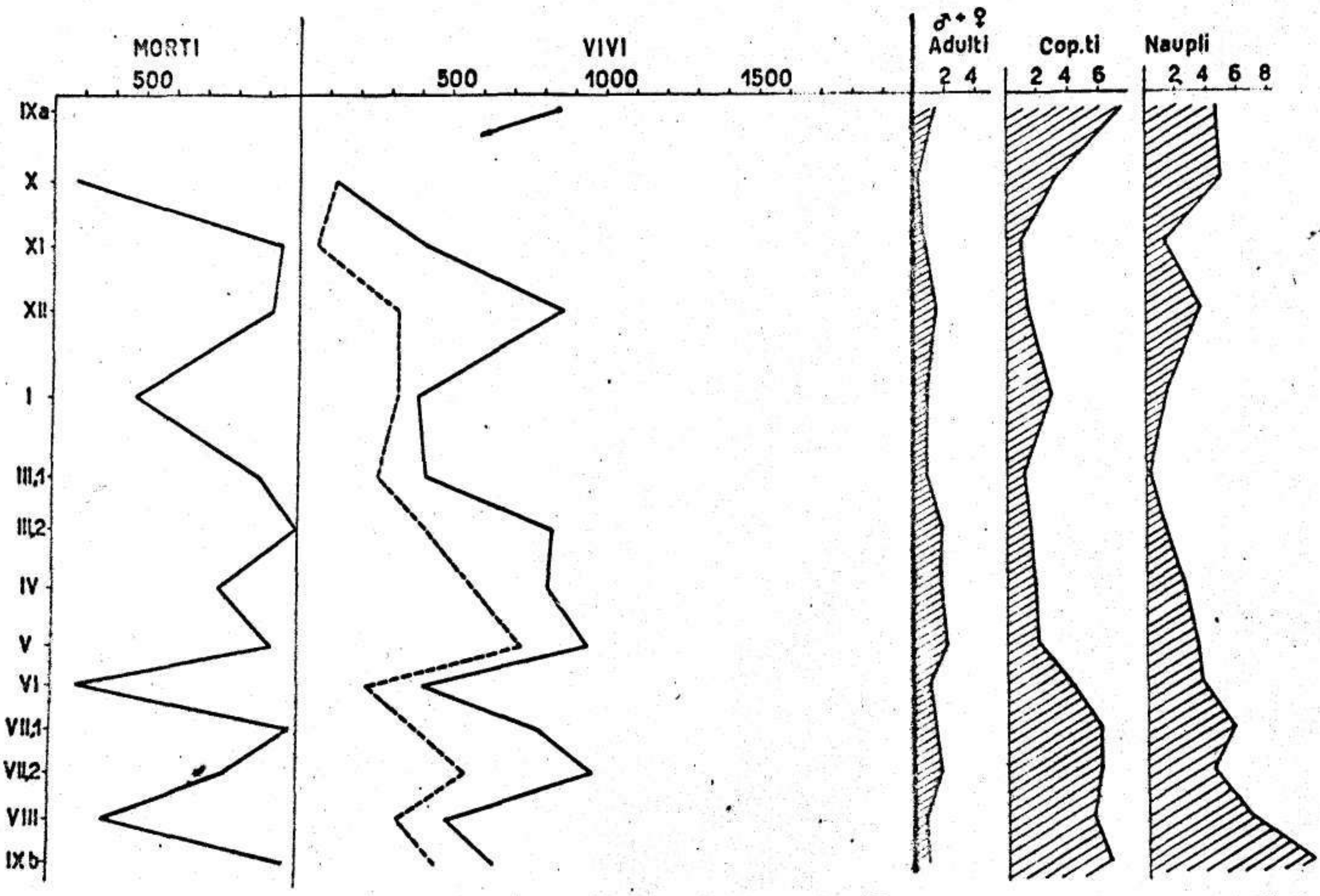

Fig. 8. - **Medie per le stazioni da 1 a 6 della elaborazione dei valori biometrici (I antenna e I segmento del cefalotorace della popolazione adulta femminile di *Eudiaptomus vulgaris*.** Mortalità/mc **intervenuta tra date successive e dimensioni della popolazione (distinta in individui residui dal precedente censimento - sopravvissuti - compresi tra la linea di base e la linea tratteggiata, e individui maturatisi a forma adulta nell'intervallo di tempo - neoadulti - oltre la linea tratteggiata). A destra: i poligoni tratteggiati indicano, in migliaia di individui per mc, le dimensioni del popolamento degli adulti (maschi + femmine) dei** copepoditi e dei naupli.

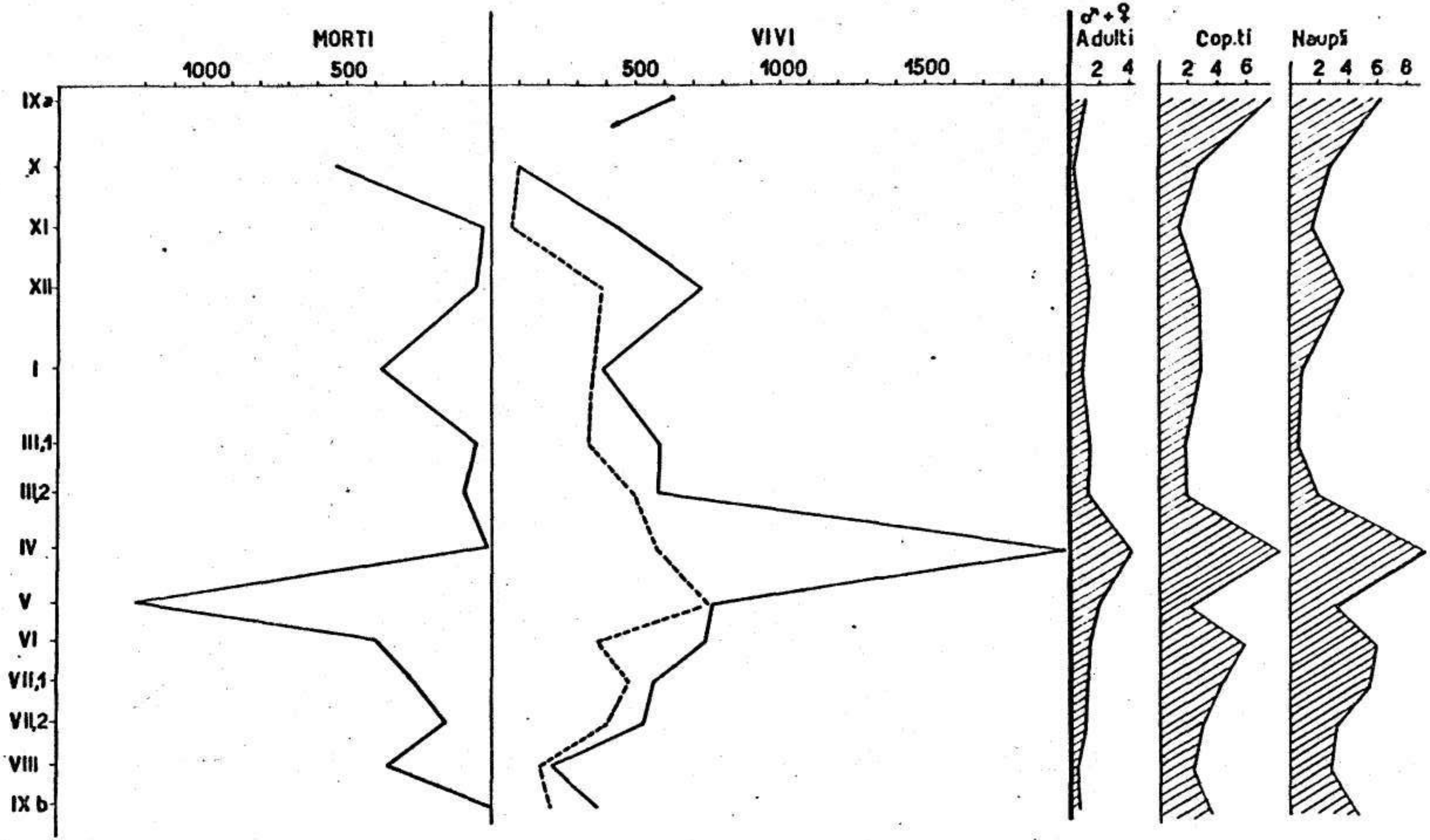

Fig. 9. - Come in Fig. 8, per le stazioni da 7 a 12.

m^3, composed of the individuals surviving at the census immediately preceding and of the individuals (neoadults) which have reached maturity within the same period of time.

From such figures one can follow how the increments in the density of population come about, how on the other hand it is logical to expect always considerable numbers of neoadults. Whilst the curves of mortality and survival show similar configurations in the two groups of stations, if still perhaps some slowing down in stations 1-6, the number of neoadults in the month of April (IV) is much greater in the southern than in the northern part of the lake.

However, the complete results of the demographic analysis are much closer for the two parts of the lake. In the group of the stations 1-6 we have collectively, during the whole year, the recruitment to the population of 3315 female neoadults in each m^3 of water between the surface and 50 m depth of water: the number of deaths is 3532 and the mean density 634·6. For the stations 7-12, such values are respectively 3313, 3571 and 612·4. The larger number of losses (deaths)compared with gains (recruits) is explicable by the lower density of population which there is in the whole lake in the month of recapitulation of the annual cycle.

Dividing the totals of neoadults by the mean density, we are able to obtain a figure which, although an average, could be expressed as the number of times in which the population is renewed in the course of one year: 5·22 (stations 1-6) and 5·41 (stations 7-12).

It is easy to see that these theoretical values in reality naturally are more modest, in as much as the greater number of neoadults occur at the times of greatest population density. If on a graph (Fig. 10) which shows the variation of population density, we superimpose the additive series of the numbers of neoadults living contemporaneously we obtain some points of intersection which give the temporal value required for the total renewal of the individuals constituting the preceding population. The values thus obtained show clearly the dependence also of this aspect of the biological cycle of the population of <u>Eudiaptomus vulgaris</u> on the thermal conditions at different seasons.

For the southern stations we have in a period of 313 days only three renewals and for the northern stations, four in a period only slightly longer (320 days), which is in accordance with what has been observed by Ravera (1954) about the number of generations in the year. One can perhaps think that as we have seen the complete values of neoadults are not detached for the two parts of the lake, one ought to take into account for the southern stations, a passive migration set up by the out-flowing current, of mature individuals from the north and which, as indicated by lateness in biological time, have greater probability of being identified as survivors.

If we accept the hypothesis that the last moult, from the ~~cpd~~ copepodid V to the adult and the mortality operating on the adult population and regularly distributed phenomenon in the period of time between censuses, we can try

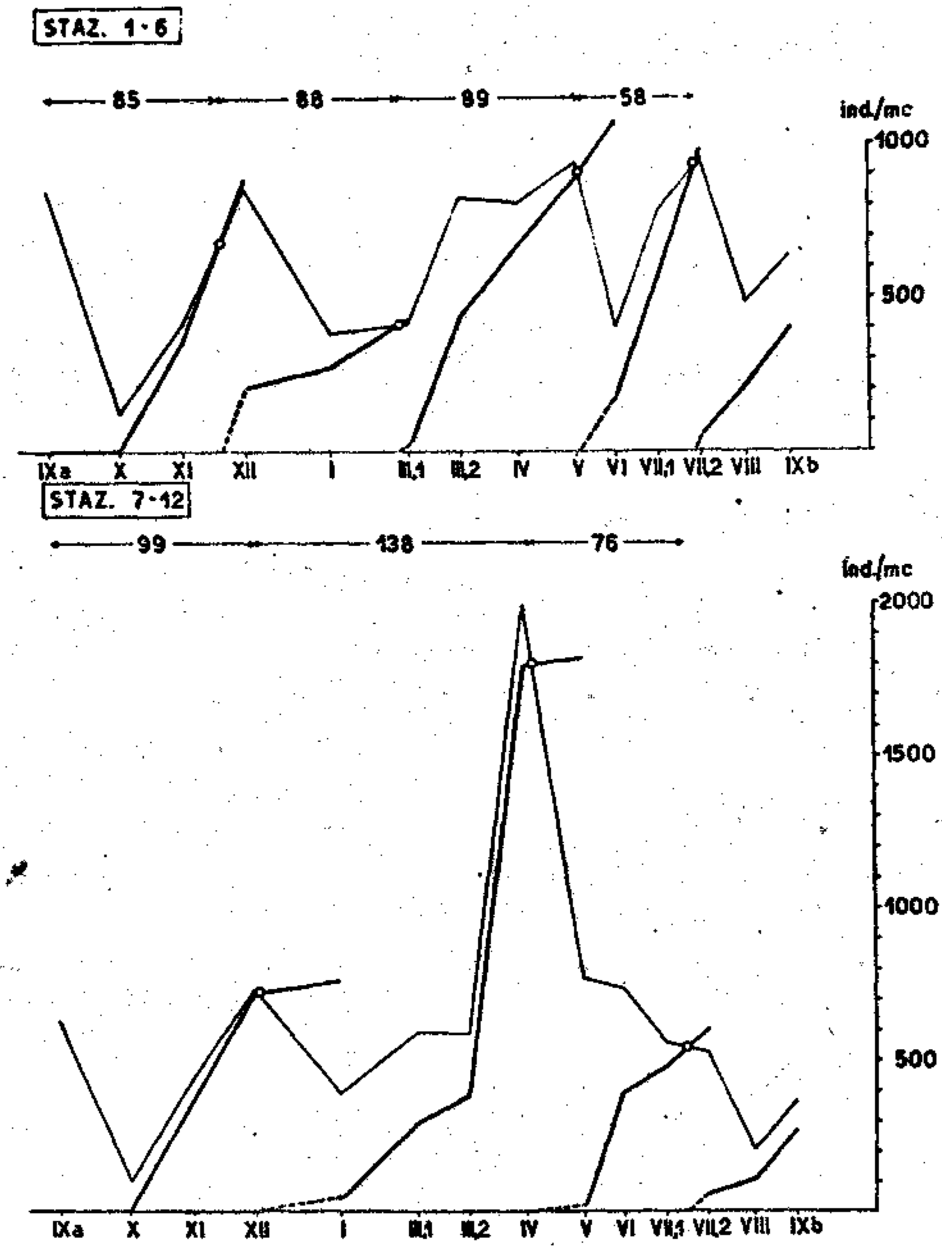

Fig. 10. - Calcolo dei tempi di completo rinnovo della popolazione adulta di *Eudiaptomus vulgaris* femmina. In tratto sottile, la densità/mc del popolamento; in tratto grosso, gli apporti cumulativi di neoadulti. L'intersezione delle due linee dà in giorni il tempo richiesto per la sostituzione.

to assign mean ages to the individuals which make up the population in each month, in the following way

$$\text{mean age of neoadults} = \frac{t^0 - t^{-1}}{2} \qquad \text{[neoadult probably = new adults]}$$

$$\text{mean age of survivors} = \frac{t^{-1} - t^{-11}}{2} + (t^0 - t^{-1})$$

where t^0 is the date of the census in question, t^{-1} and t^{-11} the dates of the two census immediately preceding.

Multiplying these mean ages by the numbers of E. vulgaris females present on any date as neoadults and as survivors, and dividing successively by the totals of the females we obtain values that indicate the number of days which the average individual has already spent in its adult stage of life and which in turn gives some idea of the youthfulness or maturity of the population.

If one tries (Table 4) to see how this character of the population is tied up with other biological variables, such as the % freq. of ovigerous females, mean no. of eggs/♀ , the sex ratio, one finds reproductive activity a little more intense in the southern stations, but on the whole, the mean values are very similar. There does not seem to be a correlation between the values of mean age and the other characters of the population which are able to have a significance as evidence of reproductive effort. Probably some results in this sense could have been reached if the female population had been examined in this respect not as a whole but separately as the adult survivors and the neoadults.

We have not collected data on the renewal of the male population but the seasonal modifications of the sex ratios which is consistent in its unfolding within the same group of stations, here leads one to think that larger differences do not exist in this sense in respect to the female population, also the biological period appears to be in some occasions notably out of phase between the two groups of stations: one sees, e.g. the situation in June (VI) when in the stations 1-6 there were available for 3 males , 2 females while at the stations from 7-12 for 3 males one had 4 females.

It appears, in each case, possible to state that in the column of water of 1 dmq in area, present between the surface and 50 m depth of water, there are coming to maturity on average, during the year, 3000 adults of Eudiaptomus vulgaris, cumulatively for both the sexes.

Using the method of calculation proposed by Elster (1954) and taking again that by Eichorn (1957) and also Edmondson, Comster and Anderson (in press), it has been possible to estimate egg-production. The calculation is based on the number of eggs present in a given space at the temperature of the strata in which the phenomenon occurs (and thus at the rate of development of the egg at that temperature) and finally in the time which separates two successive observations.

		Età media (giorni)	N° uova/ ♀ ovig.	% ♀ ovig./ totale ♀	1 ♀ :: ♂
IX a	St. 1- 6		2.32	10.62	0.53
	St. 7-12		*2.43*	*13.89*	*0.66*
X			2.59	19.28	1.00
			2.42	*16.46*	*0.68*
XI		23	3.71	3.54	0.73
		23	*3.59*	*6.61*	*0.72*
XII		29	4.38	1.83	0.66
		34	*4.12*	*3.24*	*0.75*
I		52	2.83	3.05	1.05
		54	*2.85*	*3.43*	*0.93*
III, 1		44	4.50	18.68	0.98
		42	*4.60*	*19.19*	*1.20*
III, 2		29	3.87	15.97	1.21
		40	*4.08*	*12.91*	*1.12*
IV		34	4.46	10.29	1.16
		22	*5.03*	*10.40*	*1.07*
V		37	3.69	6.22	1.22
		43	*3.53*	*9.59*	*1.38*
VI		23	4.33	6.49	1.52
		21	*3.76*	*5.53*	*0.75*
VII, 1		20	2.95	2.84	0.82
		27	*3.69*	*5.57*	*0.96*
VII, 2		22	2.92	10.90	0.80
		26	*2.98*	*3.95*	*0.83*
VIII		26	2.54	4.93	0.52
		29	*2.78*	*11.68*	*0.79*
IX b		25	3.07	3.74	0.47
		22	*3.59*	*4.01*	*0.66*
	$\overline{M}$	30.3	3.44	8.46	0.905
		31.9	*3.53*	*9.03*	*0.893*

Tabella 4.

	A t° C (0-15 m)	B Uova presenti/ mc medio	C Tempo tra i prelievi (giorni)	D Rata di sviluppo	B·C·D Uova prodotte nel periodo in 1 mc
IX a	17,27	130	31	0,301	1.213
X	14,38	65	35	0,237	539
XI	10,98	81	32	0,148	384
XII	8,26	59	42	0,094	233
I	6,99	237	37	0,080	702
III, 1	7,11	423	26	0,081	891
III, 2	8,22	556	30	0,093	1.551
IV	11,03	470	28	0,149	1.961
V	14,35	184	19	0,235	822
VI	15,86	112	21	0,272	640
VII, 1	17,32	137	21	0,302	869
VII, 2	19,11	122	22	0,341	915
VIII	19,02	62	20	0,340	422
IX b					
					11.142 uova prodotte/ mc/anno

Tabella 5.

For the Eudiaptomus gracilis of Lake Maggiore we have used the reciprocal (rate of development) of the values of time required for the hatching of the egg calculated by Elster for Eudiaptomus gracilis in Lake Constance at different temperatures. D. gracilis is shaped much as D. vulgaris and Lake Constance is not remarkably different in its thermal regime from that in Lake Maggiore. The adoption of that constant is therefore justified.

The temperature at which is effected the opening of the eggs in different seasons has been taken as the mean in the first 15 m of water between successive dates. Thus one is limited to that depth of water because in effect it is aggregated the vast majority of ovigerous ♀♀ of E. vulgaris. On the other hand, the extension of the level to 20 m depth which seems truly the maximum allowable results in a diminution of the estimated values of only about 5%.

The calculations thus made (Table 5) gives the result that one has an annual production of 11·142 eggs per m^3 of water between the surface and 50 m depth. This value, expressed, as one is done in the case of the adults, for a column of water 1 dm^2 in area gives 5·571 eggs produced during the year which signifies that only 54% of the eggs complete their development to form adults the remaining 46% being eliminated before the fulfilment of their biological cycle.

SUMMARY

The biometrical study of suitably chosen characters (Fig. 2) has shown the existence of definite seasonal modifications within an adult female population of the pelagic copepod *Eudiaptomus vulgaris* Schmeil (Tables 1 and 2, Figs. 4 and 5).

It has been possible to distinguish at each census individuals which have reached maturity at an earlier period from those which have become mature more recently, by noting the number of structures biometrically identical at preceding dates.

Diagrams have been constructed (Figs. 8 and 9) which show the variations during an annual cycle in the introduction into the population of new adults, in the survival and in mortality of adults already present at a previous census.

On the basis of these data, the times required at different periods of the year for a complete renewal of the population have been calculated, together with the mean age of the individuals constituting the adult population at each period (Fig. 10, Table 4).

The results obtained for the twelve stations studied in the Lago Maggiore lead the conclusion that, on the average, during an annual cycle six individuals of *Eudiaptomus vulgaris* (both sexes included) reach maturity in each litre of water between the surface and a depth of 50 metres.

It was also possible to calculate the eggs production which averaged 11,14/l/year inside the same layer. It is then possible to state that about one half of the larvae, between the egg and the fifth copepodite, dies before reaching maturity.

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Notice

Please note that these translations were produced to assist the scientific staff of the FBA (Freshwater Biological Association) in their research. These translations were done by scientific staff with relevant language skills and not by professional translators.